FuelCell Energy

Ultra-Clean, Efficient, Reliable Power

DFC Opportunities

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reliable, efficient, ultra-clean

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Direct Fuel Cell Challenges

- Baseline products cost-competitive with government subsidy at locations with very high cost-of-electricity
- Company sponsored R&D focusing on marginal gains to make the DFC products cost-competitive in regions with high cost-of-electricity

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Direct FuelCell Opportunities

- Needs large scale market penetration to enjoy the fruits of this transformational technology
- Needs drastic reduction in cost-of-electricity to achieve large scale deployment
- Requires high risk research to achieve the required COE reduction (increase power density, enhance life and lower cost)
  - Increase stack power from 350 net kW to 500 net kW
  - Enhance stack service life from 5-yr to 10-yr
  - Additional 20% cost reduction by design and volume production

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DFC Life Improvement Opportunities

- **Baseline design life 5-yr**
- Life (5-yr) limiting factors
  - NiO dissolution from cathode and deposition in the matrix
  - Electrolyte loss from matrix causing gas leakage and cell internal resistance increase
- Desired life 10-yr for wide spread commercial success

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Performance Improvement Opportunity

- Stack output has increased by a factor of three over last twelve years
- **Current stack output is 350 kW net AC**
- Another 40% increase is achievable
  - New cathode development will be required to achieve the desired goal

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Stack Cost Reduction Opportunity

- **Stack module cost is ~two-third of the plant cost**
- Low hanging opportunities:
  - Stream lining of cell assembly process allowing automatic cell assembly

    Develop human touch free assembly line concept

    Develop automated components joining techniques.

    Demonstrate cell components assembly without human touch
  - Matrix manufacturing process improvement to allow higher yield

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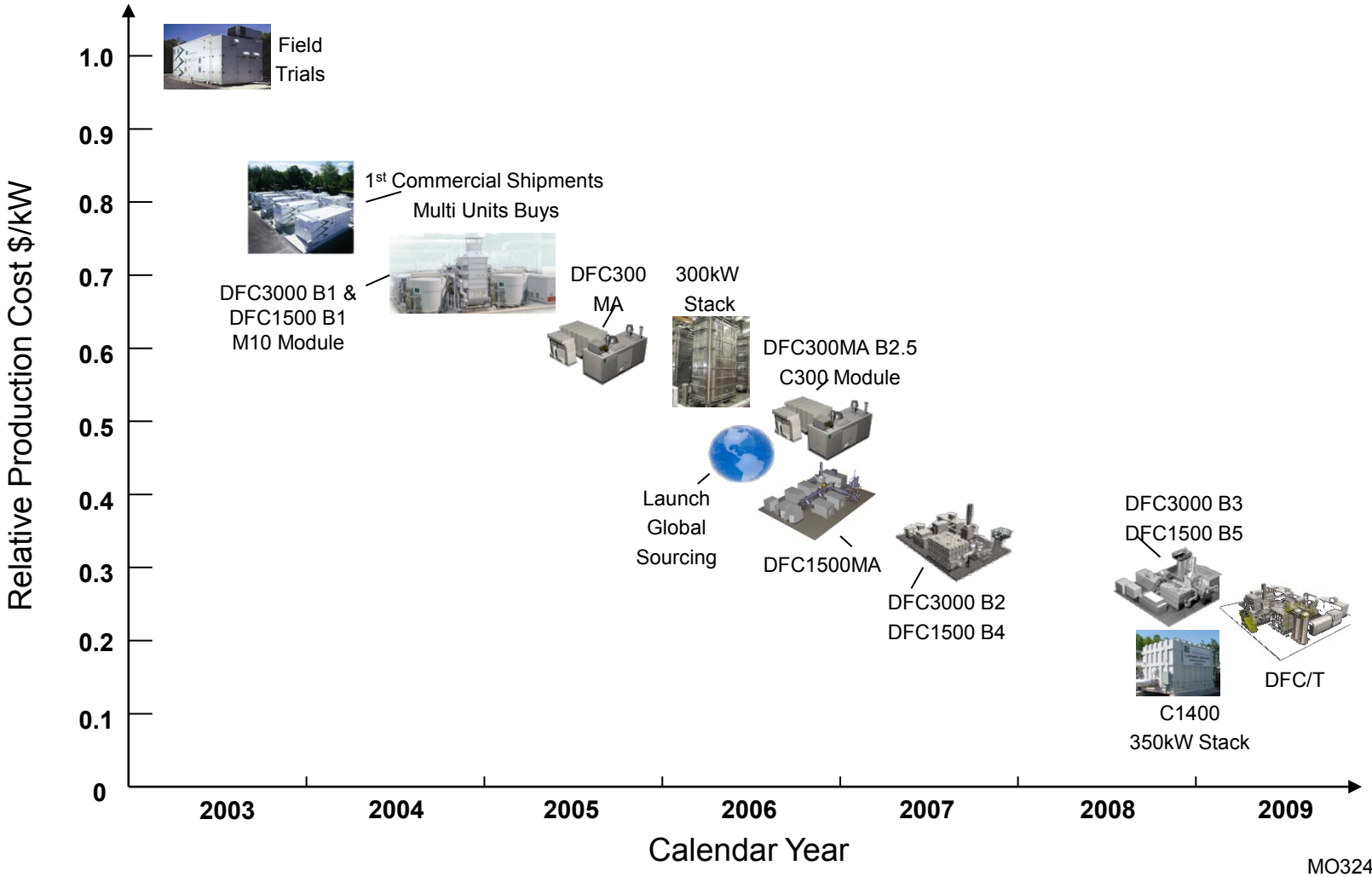
The History of DFC Products Cost Reduction



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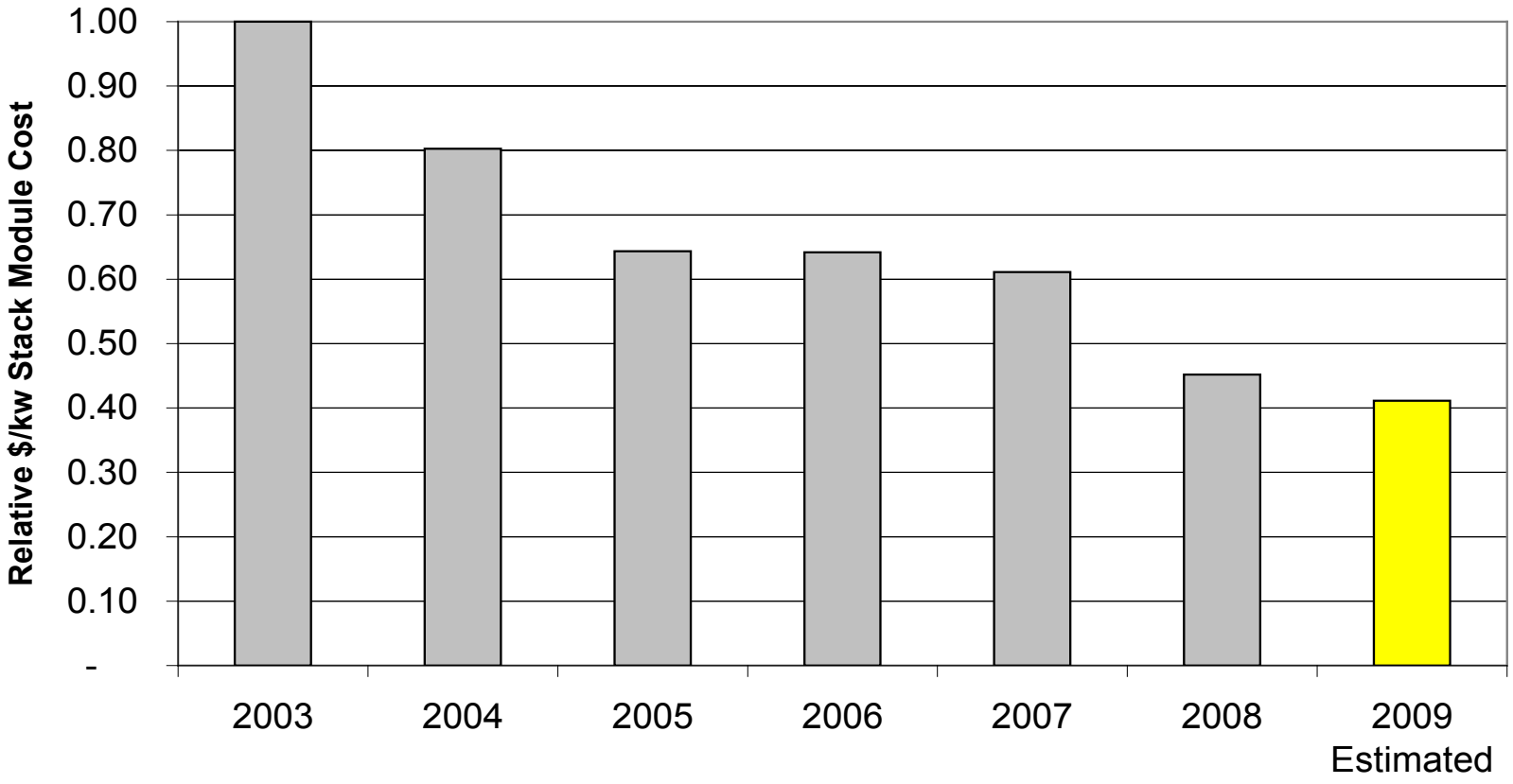
Normalized Direct Fuel Cell MW Module Cost Reduction Progress



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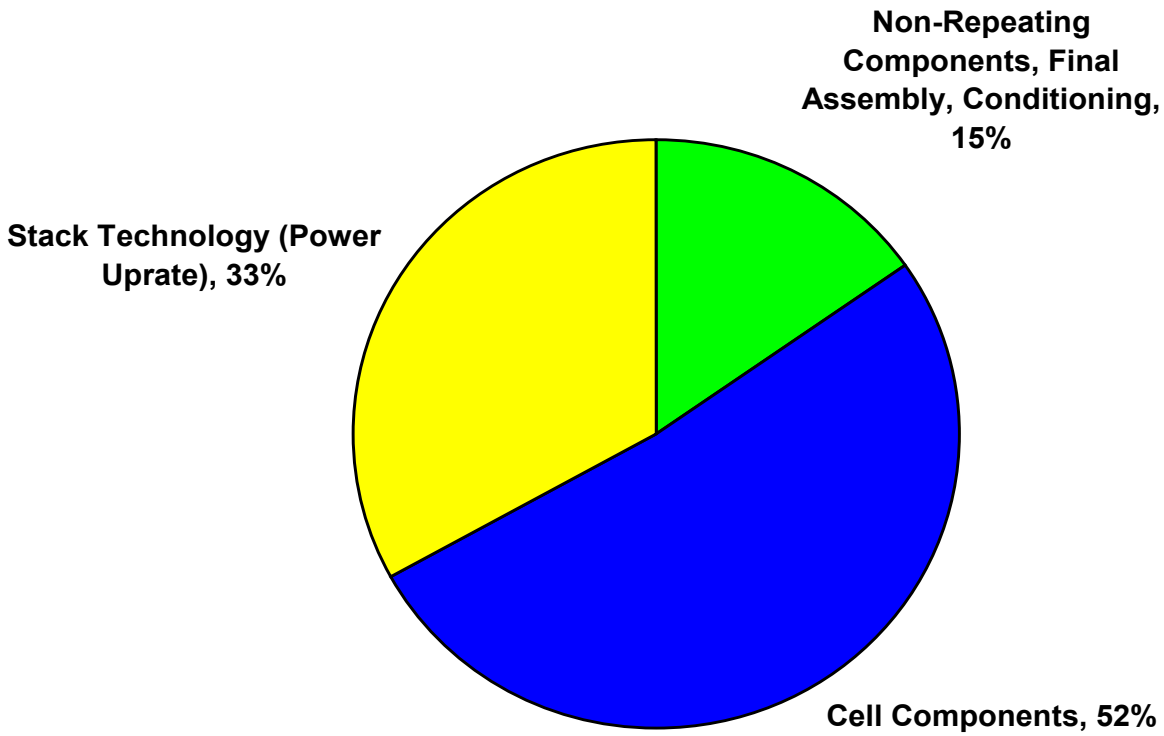
Source of Realized Cost Savings DFC Module (2003 – 2009)



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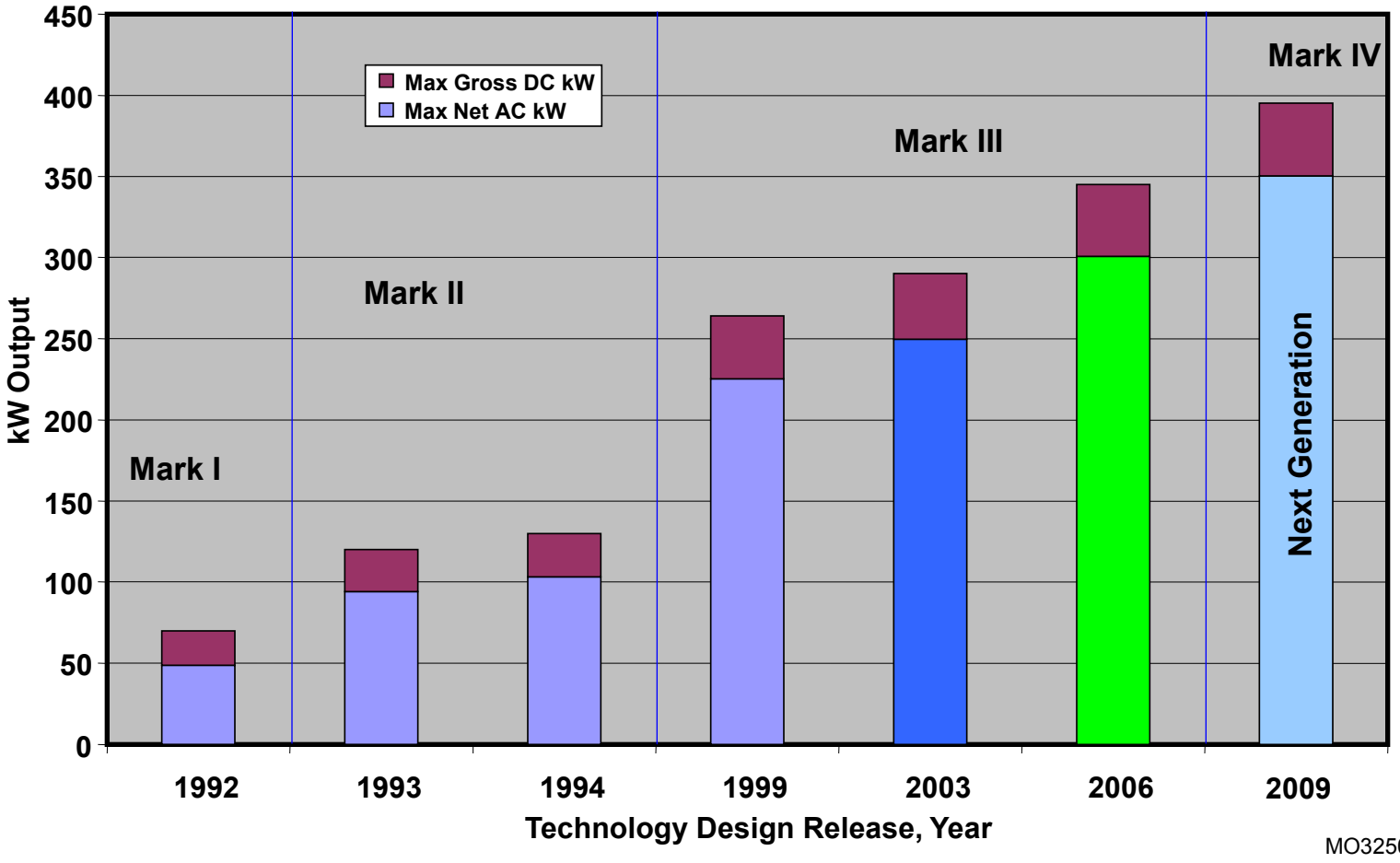
Full-size Stack for Output Improvement Over the Years



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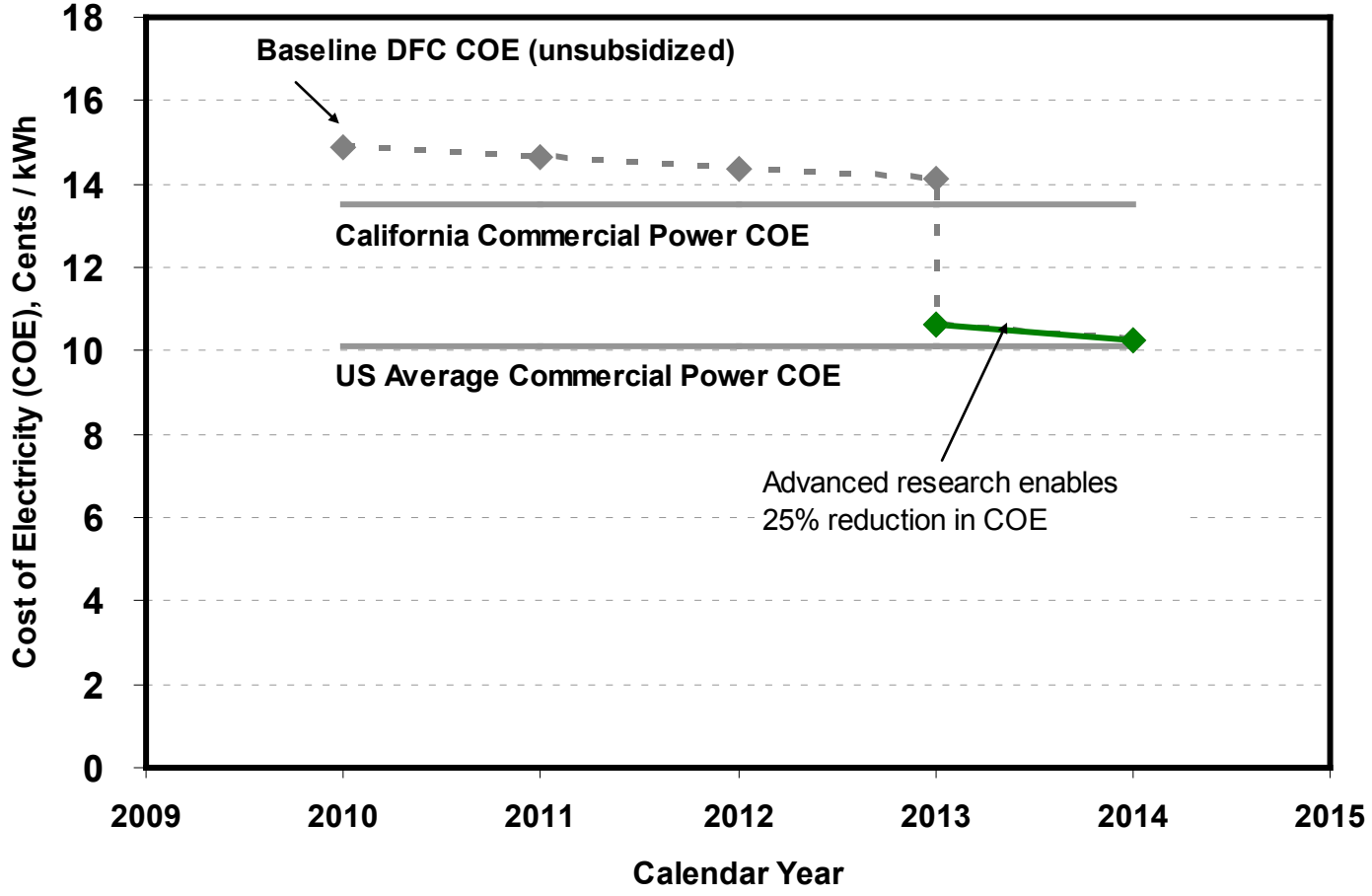
DFC Cost-of-Electricity Reduction by 40% Performance and 100% Life Improvements



DFC COE based on installed cost for DFC3000 product. Capital costs amortized over 15 years, fuel cost at $7.5/MMBtu

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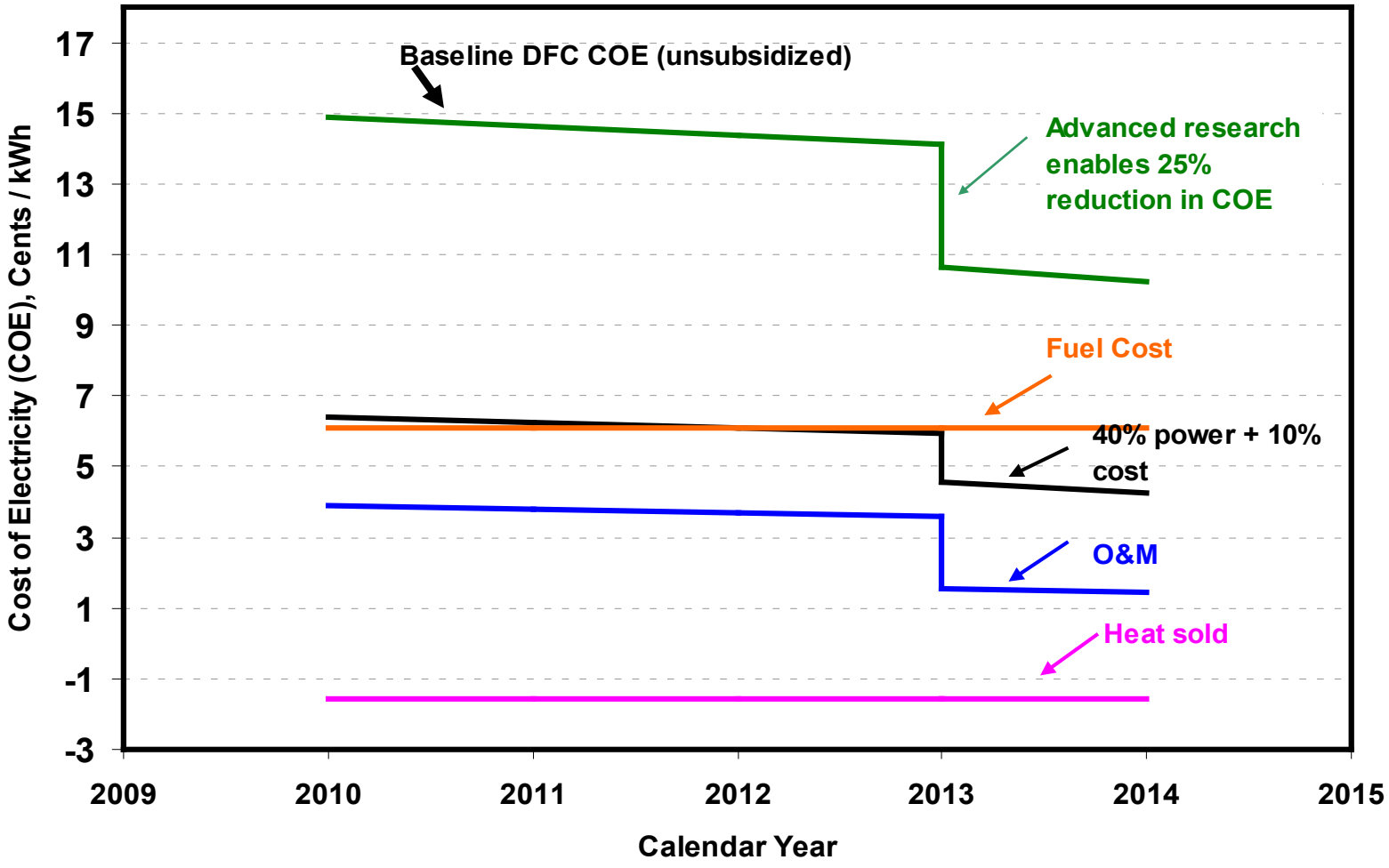
Cost of Electricity Breakdown



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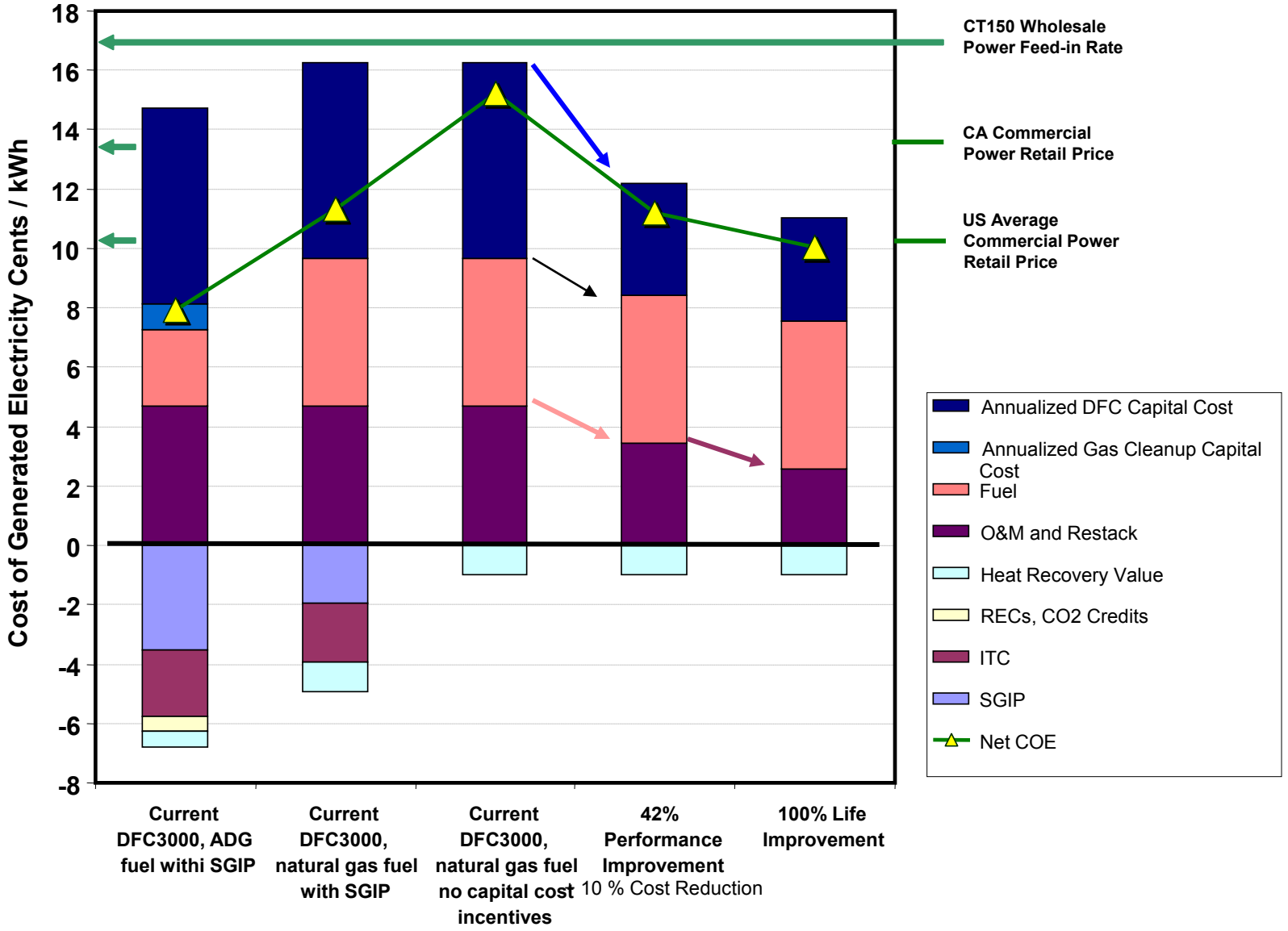
Impact of Target Improvements: Opens Up Unsubsidized Markets



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Potential Impacts

Wide spread adaptation of the DFC will result from drastic COE (~3-4 cents/kWh) reduction and will lead to immeasurable national benefits. Simply 0.2% capture of the total capacity will lead to:

- **Reduces GHG emissions by ~20 million tons of CO_2 per year) to combat climate change**
- **Saves fuel (~50 million barrels of oil equivalent per year) improving energy security**
- **Ensures US leadership in the energy technology field**
- **Creates~300,000 new green technology jobs**
- **Generates billions of dollars (~$10 billion) in foreign sales**

Appendix

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Estimation of Impacts

Assumptions	USA	Rest of the World	Total
Total Installed Capacity in 2006[1], MW	964,000	3,048,000	4,012,000
Replacement Market, 3% per year	28920	91,440	120,360
Growth Market, 1.0% USA[1] and 2.2 % rest of the world[2]	9,640	67,056	76,696
Toatl New Installations, MW	**40,000**	**160,000**	**200,000**
Yearly DFC Capture starting 2015, 5% of US market and 3% of World Replacement Market, MW	2,000	4,800	6,800
% penetration of the Total	0.21	0.16	0.17
Fuel Cell Sale , $X10^6 ($1800 per kW)	3,600	8,640	12,240
Fuel Cell Stack Replacement + Maintenance (15%), $10^6	540	1,296	2,000
Total business, $10^6	4,000	10,000	14,000
Job (direct+Indirect) creation, # (23 jobs per $10^6)[3]	**100,000**	**200,000**	**300,000**
Total Fuel Cell Power Per Year (@ 90% Capacity factor), MW-hr	15,770,000	37,840,000	53,610,000
CO_2 Emissions Avoided,million tons per year	5	12	18
SOx Emissions Avoided	0.06	0.14	0.19
Nox Avoided	0.02	0.06	0.08
PM_{10}	0.0019	0.00	0.01
Fuel Savings, million barrels/yr oil equivalent	10	30	50

1. Energy Information Administration International Energy Annual 2006

2. *EIA Press release, April 14, 2004, "World net electricity consumption nearly doubles over the projection period, from 13,290 billion kilowatthours in 2001 to 23,072 billion kilowatthours in 2025"* (estimated to be 2.2%)

3. Projected by Chris Bentley of FCE